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The response of multinationals' foreign exchange rate exposure to macroeconomic news ☆

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ABSTRACT

We use intraday data to estimate the daily foreign exchange exposure of U.S. multinationals and show that macroeconomic news affects these firms' foreign exchange exposure. News creates a substantial shift in the joint distribution of stock and exchange rate returns that has both a transitory and a persistent component. For example, a positive domestic demand surprise, as reflected in higher-than-expected nonfarm payroll, increases the value of the low-exposure domestic activities and results in a persistent decrease in foreign exchange exposure.

1. Introduction

Changes in foreign exchange rates affect the cash flows and therefore the values of internationally active firms. This exchange rate exposure varies over time, is not directly observable, and therefore is challenging to estimate (see Jorion, 1990; Boudt et al., 2015). Variations may reflect changes in the firm's activities or the characteristics of the industry or the nature of the structural shocks to foreign exchange markets. Previous empirical work has dealt with time variation either by splitting the sample (e.g., Jorion, 1990; Williamson, 2001), using rolling windows (e.g., Glaum et al., 2000) or by modelling exchange rate dynamics (e.g., Boudt et al., 2015).

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The present paper extends the literature by using intraday exchange rate and stock price data to estimate each day's exposure coefficient to better track the changing foreign exchange sensitivity of 182 U.S. multinationals over 2008–2014. The average firm exposure is positive — i.e., a U.S. dollar depreciation raises U.S. stock prices — but varies substantially, from clearly negative in 2008 to zero in 2013–14. In addition, exposure also exhibits sizable day-to-day jumps that are related to news, implying that they are genuine changes rather than just estimation noise.

We show that news releases produce both transitory and persistent effects on exchange rate exposure. The existence of two types of effects suggests to us that announcements provide information on both the state of the economy and the sensitivity of stock prices to exchange rates. We argue that information pertaining to the state of the economy that does not influence expectations of the relative future profitability of import and export divisions should have only a transitory effect on the exchange rate and stock returns. In contrast, information about the relative profitability of future domestic and international operations should persistently affect the foreign exchange exposure of the firm.

Our study contributes to the large literature that studies the effects of macroeconomic and policy announcements on asset prices. Previous work has found that such prices quickly incorporate macroeconomic news (Andersen et al., 2003; Andersen et al., 2007; Neely and Dey, 2010) and central bank communications (Bauer and Neely, 2014; Dewachter et al., 2014; Neely, 2015). Mun (2012) documents the joint response of foreign exchange and stock markets to macro announcements while Lahaye et al. (2011) study the effect of news on cojumps in stock prices, interest rates and exchange rates.

Another substantial literature characterizes foreign exchange rate exposure dynamics. The theoretical literature has rationalized foreign exchange exposure for multinational firms (Shapiro, 1975) while the empirical literature has identified significant determinants of exposure that are associated with firm characteristics: industry structure, economic development, the business cycle and the level and recent behavior of the exchange rate. He and Ng (1998) relate exposure to the relative importance of foreign activities and the firm's hedging behaviour. Allayannis and Ihrig (2001), Bodnar et al. (2002), Dominguez and Tesar (2006), Doukas et al. (2003), Gao (2000) and Williamson (2001) have modeled exposure dynamics as a function of industry and firm structure. Jorion (1990) shows that the exchange rate exposure depends on the level of economic development. Francis et al. (2008) and Chaieb and Mazzotta (2013) find that firm and industry characteristics explain cross-sectional differences but macroeconomic conditions influence time variation. Specifically, Chaieb and Mazzotta (2013) show that domestic recessions increase the exposure of multinational firms. Boudt et al. (2015) document the dependence of exposure on the recent behavior of the exchange rate, that is, on the moneyness of the option to export.

Our paper connects these two literatures by linking foreign exchange exposure dynamics to news on macroeconomic conditions. Several macroeconomic announcements systematically affect foreign exchange exposure, including nonfarm payroll (NFP) and Federal Open Market Committee (FOMC) target announcements. Foreign exchange exposure decreases persistently following positive NFP and FOMC target surprises because both signal a strengthening domestic economy and therefore an increase in the relative importance of the domestic and import activities of the firm. In contrast, price index surprises, such as those from export and producer prices, have a significant transitory impact on exposure. A positive price index surprise, for instance, temporarily decreases foreign exchange exposure. Sectors exhibit some variation, although most conclusions hold generally.

The remainder of the paper proceeds as follows. Section 2 develops the hypotheses. Section 3 discusses the data and methodology. Section 4 presents the estimated foreign exchange rate exposures. Section 5 characterizes the foreign exchange rate exposure dynamics. Section 6 details foreign exchange exposure by sectors and by level of foreign sales. It also characterizes market and *incremental* exposure. Section 7 concludes.

2. Definitions and hypothesis development

2.1. Definitions

One can define both the *total* exposure and the *incremental* exposure of a firm's value to exchange rate changes (see, e.g., Bodnar and Wong, 2003). We initially study the total exposure, which is the parameter of interest for standard hedging purposes (Liu et al., 2015). Adler and Dumas (1984) define total foreign exchange rate exposure as the elasticity of a firm's value to changes in the exchange rate. More precisely, let $V_{i,t}$ be the value of firm i at time t and let S_t be the exchange rate in units of domestic currency per unit of foreign currency. Then, the total foreign exchange exposure of firm i at time t, $\delta_{i,t}$, is the total derivative of the firm's log value with respect to the log exchange rate:

$$\delta_{i,t} = \frac{\mathrm{d}\log V_{i,t}}{\mathrm{d}\log S_t}. \tag{1}$$

This total exposure can be estimated as the slope coefficient from an ordinary least squares (OLS) regression of a firm's stock log changes on log exchange rate changes,[1] *i.e.*, as the ratio of the sample stock price-exchange rate covariance ($\hat{\sigma}_{is,t}$) to the exchange rate variance ($\hat{\sigma}^2_{s,t}$):

[1] Following Jorion (1990) and most subsequent work in this field, we use just one (trade-weighted) exchange rate as regressor, but the regression can easily be expanded with multiple exchange rates on the right hand side.

$$\hat{\delta}_{i,t} = \frac{\hat{\sigma}_{is,t}}{\hat{\sigma}^2_{s,t}}. \tag{2}$$

Usually, the OLS estimator is used with a rolling sample. Jorion (1990) adds market returns as an additional regressor, but the resulting currency sensitivity (incremental exposure) is quite different, as discussed in Section 6.4.

To understand the effect of macroeconomic news on total foreign exchange exposure, we rewrite the firm value as the sum of the values of the firm's divisions with a positive exposure coefficient, i.e., those in exporting or import-competing activities (subscript x), the divisions with a zero coefficient, i.e., those in a non-tradeable division in a sheltered sector (subscript d), and the divisions with a negative exposure coefficient, i.e., those that engage in activities that rely on imported inputs or have the option to import instead of buying or producing locally (subscript m): $V = V_x + V_m + V_d$. [2] The firm's exposure coefficient is the weighted sum of the division exposures:

$$\delta = \frac{\mathrm{d}\log V}{\mathrm{d}\log S} = \frac{1}{V}\frac{\mathrm{d}(V_x + V_m + V_d)}{\mathrm{d}\log S} = w_x\delta_x + w_m\delta_m, \tag{3}$$

where $w_x = V_x/V,\ w_m = V_m/V$ (the weights at the beginning of the period) and using $\mathrm{d}V_d/\mathrm{d}\log S = 0$, by definition of the domestic division. A net exporting firm has positive exposure and benefits from a foreign currency appreciation while a net importer has negative exposure.

This decomposition formalizes the intuition that the level of the exchange rate influences the relative weight of export and import activities and foreign exchange exposure. More precisely, the firm may tactically adjust volumes and prices in each of its three divisions. Factors such as exchange rate movements and changes in international business prospects affect export decisions, the divisions' relative weights and the firm's overall exposure. For instance, an appreciating foreign currency or strengthening foreign demand boosts the value of the export divisions and increases exposure.

In addition to these tactical decisions, the firm can take irreversible strategic decisions, like building new factories or entering new markets, that require substantial lump-sum investments. These can abruptly change cash flows but still have gradual impacts on weights as the market continuously updates the likelihood of such a strategic choice. In short, total exposure fluctuates continuously in light of news and the structure of the firm's cashflows. The decomposition in Eq. (3) forms the basis for most of the hypotheses that we develop in the next subsection.

2.2. Hypothesis development

Ceteris paribus, a depreciation of the dollar gives U.S. multinationals an advantage exporting to world markets by reducing the relative costs of U.S. goods but it will also make imported intermediate goods more expensive. So, the value of the dollar influences U.S. firms' export and import strategies and thus their foreign exchange exposure. Such exposure changes do not need any adjustments in capital stocks; adjustments in prices and quantities can affects the weights too. As exchange rates are persistent, we expect those changed weights of the export and import businesses to persist. In addition, firms could react strategically to produce long term effects on exposure. For example, a U.S. firm might expand its export business following a decline in the dollar, which will raise its foreign exchange exposure. However, entering a foreign market or expanding production capacity usually implies irreversible investments. We therefore argue that firms revise their import/export strategy only rarely, usually after large accumulated changes in the currency values. Since exchange rates and stock prices themselves are persistent, we therefore expect that variation in the firm's exchange rate exposure has a persistent component beside the transient effects. This leads us to hypothesize:

Hypothesis 1. Foreign exchange rate exposure is positively serially correlated.

We know that foreign exchange exposure varies over time and we hypothesize that macroeconomic news influences this variation. We distinguish between transitory and persistent effects. A transitory shift in exposure arises because macro news affects both the stock's price and the exchange rate. These joint movements tend to be larger than moves on other days. If the news pushes the exchange rate and the stock's value in the same direction, the result may be an above-average foreign exchange exposure, and *vice versa*. Such a change in exposure is transient and may be largely unexpected. Higher exchange rate volatility is not sufficient to increase exposure: from $\delta_i = \rho_{is}\sigma_i/\sigma_s$ in Eq. (2), a higher exposure requires higher correlation and/or a bigger increase in stock volatility than in exchange rate volatility.

Persistent shifts in exposure probably reflect the combined effects of changes in the relative weights and exposures of the export, import and domestic divisions. Suppose, for instance, that negative news about the U.S. economy depreciates the U.S. dollar and improves cash flows from exports while reducing those from imports. Foreign exchange exposure increases with export activities.

Based on these arguments, we state following hypotheses:

Hypothesis 2a. New information about the value of the firm and the exchange rate immediately but transiently raises foreign exchange rate exposure.

[2] The three labels oversimplify. For our purposes, the export part includes *e.g.,* foreign assets, and the import part accounts for *e.g.,* foreign liabilities.

Hypothesis 2b. New information about the long-term sensitivity of the firm's value to exchange rate changes persistently affects exchange rate exposure.

3. Data and methodology

This section first introduces methods to estimate daily foreign exchange exposure with high-frequency data. We then describe the data on firms, foreign exchange, and the macroeconomic announcements. Finally, we present the equation that relates the macroeconomic news announcements to foreign exchange exposure.

3.1. Estimating time-varying foreign exchange rate exposure

The foreign exchange exposure coefficient $\delta_{i,t}$, as defined in Eq. (1), is not directly observable. When one assumes the exposure coefficient to be static, it is common to follow Adler and Dumas (1984) and estimate $\delta_{i,t}$ as the ordinary least squares (OLS) coefficient from the regression of the log returns of stock i on log exchange rate returns. The resulting coefficient estimate is the minimum variance hedging ratio (Johnson, 1960; Stein, 1961; Dumas, 1978).[3] This ratio is of practical interest to a portfolio manager who hedges a position in equities, or in asset pricing, where the returns on hedged stocks follow a simple one-factor CAPM in a multi-currency setting (Sercu, 1980).

To account for time variation in $\delta_{i,t}$, previous studies either split their sample or use rolling estimation windows (see, e.g., Jorion, 1990; Bartram and Bodnar, 2012). This unrealistically assumes that parameters are constant over relatively long time periods. In this paper, we use intraday price data to obtain timely estimates of the exchange rate exposure. For each day t, we regress the ten-minute stock returns of firm i on ten-minute exchange rate returns:

$$r_{i,t,k} = \alpha_{i,t} + \delta_{i,t} s_{t,k} + \epsilon_{i,t,k}, \tag{4}$$

for ten-minute periods $k = 1, \ldots, K$, where $r_{i,t,k}$ denotes the log return of stock i during the k^{th} intraday period on day t, $s_{t,k}$ denotes the log exchange rate return over the same time interval as $r_{i,t,k}$, and $\epsilon_{i,t,k}$ is the error. To mitigate problems from microstructure noise or non-synchronous trading, we sample stock and exchange rate data every ten minutes between 9:30 a.m. and 4:00 p.m. EST.

3.2. Data

Our initial sample consists of the 676 U.S. firms in the S&P 500 index at any point between May 2008 and December 2014 (1672 trading days). We exclude financial firms and restrict our sample to internationally active firms by requiring that the firms' foreign sales relative to total sales exceed 10% for each year over our sample period (see Jorion, 1990, among others; Allayannis and Ofek, 2001).[4] Applying these criteria produces a sample of 182 firms, which Table 1 describes. The average annual foreign sales ratio for these 182 firms is nearly 50%, substantially exceeding the required 10%. The rightmost column of Table 1 shows that theses firms represent over 50% of the S&P 500 market capitalization between 2008 and 2014. Thomson Reuters Datastream provides the annual accounting data for these 182 firms, including total and foreign sales. CRSP provides data on the stocks' market capitalizations. The Trades and Quotes (TAQ) database provides high-frequency stock prices.

Olsen and Associates provide the exchange rate series. The exchange rate return is the return on a trade-weighted exchange rate defined as units of USD per unit of a basket of foreign currencies, where the Federal Reserve provides annual trade weights, which Table 1 of the Supplementary Appendix reports. An increase (decrease) in the index means a depreciation (appreciation) of the USD. Fig. 1 plots the trade-weighted index.

Table 2 summarizes International Money Market Services (MMS) data on the expected (surveyed) and realized macroeconomic indicators, which we select on the basis of previous studies.[5] We pool the three GDP announcements and consider them as one type of announcement for parsimony's sake. The FOMC releases announcements on monetary policy every six weeks. We distinguish between conventional federal funds target announcements and unconventional policy announcements that influence long yields. When the FOMC target rate approached the zero lower bound at the end of 2008, the Federal Reserve began to implement quantitative easing and forward guidance to influence long-term yields (Wright, 2012; Kiley, 2014). Following Bauer and Neely (2014), we measure the unconventional monetary policy surprises by the change in the ten-year yield.

As in Balduzzi et al. (2001), we standardize the releases by subtracting the MMS survey expectation and dividing that series of differences by the series' own standard deviation to render the announcement coefficients comparable. The surprise ($Surp_{j,t}$) for fundamental j ($j = 1, \ldots, J$) at day t is:

$$Surp_{j,t} = \frac{A_{j,t} - E_{j,t}}{\tilde{\sigma}_j}, \tag{5}$$

[3] Often, the Adler-Dumas model is extended with a market index. We discuss the incremental foreign exchange rate exposures estimated using this model in Section 6.

[4] The foreign sales are defined as the sales by foreign affiliates, not the export sales of the firm.

[5] Definitions of the macroeconomic indicators are included in the Supplementary Appendix.

Table 1
Firm specific characteristics for annual foreign-sales-to-total-sales ratio and market capitalization of the 182 U.S. firms between 2008 and 2014. This table shows, for each year between 2008 and 2014, the average, first, second and third quartile of the annual foreign sales relative to total sales ratio and of the annual market capitalization, together with the average total weight the 182 firms represent in the S&P 500 index (in %).

	Foreign sales (%)				Market cap (in $bn)				Weight in S&P 500
	Mean	Median	25%	75%	Mean	Median	25%	75%	Mean (%)
2008	47.08	46.59	31.01	60.88	31.93	34.34	26.27	35.77	57.20
2009	47.16	47.00	30.94	60.94	27.59	27.45	25.03	30.37	58.78
2010	48.57	47.00	30.78	63.43	32.88	32.85	31.50	34.26	57.33
2011	50.01	49.29	34.50	49.30	37.07	37.39	36.01	38.34	53.90
2012	50.33	49.49	34.48	49.49	39.43	39.52	38.65	40.24	55.89
2013	49.22	47.79	31.91	47.79	44.15	44.13	42.18	45.50	53.31
2014	49.17	48.29	32.48	48.29	49.05	49.15	48.25	49.97	52.92

Fig. 1. Trade-weighted exchange rate index over period May 2008 to December 2014. The rates are expressed in U.S. dollars per unit of foreign currencies.

Table 2
Macroeconomic announcements. The table provides an overview of the scheduled macroeconomic announcements included in the analysis over the period 2008–2014. Frequency: the frequency at which news on the fundamental is announced with Q: quarterly, M: monthly and 6 W: every 6 weeks. Time: announcement time in Eastern Standard Time (EST). First release: first release date of announcement in our sample. Observations: total number of observations. Mean: average surprise. # pos.: number of positive surprises. # neg: number of negative surprises.

Announcements	Variable name	Frequency	Time (EST)	First release	Observations	Mean	# pos.	# neg.
Real activity announcements								
Real GDP Advance	GDP Adv	Q	8:30	07-31-2008	26	0.08	11	12
Real GDP Preliminary	GDP Prel	Q	8:30	05-29-2008	27	−0.08	10	13
Real GDP Final	GDP Fin	Q	8:30	06-26-2008	27	−0.24	8	14
Employees on NFP	NFP	M	8:30	06-06-2008	79	−0.14	34	44
Inflation announcements								
Consumer price index	CPI	M	8:30	05-14-2008	80	−0.10	21	34
Producer price index	PPI	M	8:30	05-20-2008	80	0.03	35	37
Export price index	EXPPI	M	8:30	05-13-2008	80	−0.08	41	35
Trade announcements								
Trade Balance	TRADE	M	8:30	05-09-2008	80	0.08	42	38
Federal Open Market Committee (FOMC)								
Federal funds target	FOMC TARGET	6 W	14:15	06-25-2008	52	0.20	48	4
Federal funds 10-y yield	FOMC 10y	6 W	14:15	06-25-2008	52	0.06	25	27

where $A_{j,t}$ is the announced value of fundamental j at day t, $E_{j,t}$ is the survey expectation, and $\hat{\sigma}_j$ is the sample standard deviation of $A_{j,t} - E_{j,t}$.

3.3. Modelling macro news effects on the foreign exchange exposure

To test the effects of macroeconomic news on exchange rate exposure dynamics, we must define the functional relationship linking the macroeconomic news to that exposure. We initially test our hypotheses with the average exposure across the 182 firms in the sample:

$$\bar{\delta}_t = \frac{1}{182}\sum_{i=1}^{182}\hat{\delta}_{t,i}. \tag{6}$$

In Section 4 we show that the average exposure summarizes the substantial common inter-temporal covariation in the cross-section of exposure. Our results are robust to exposure measures based on sector and foreign sales.

The model linking the surprises in the macroeconomic announcements ($Surp_{j,t}$) to the average foreign exchange rate exposure coefficient ($\bar{\delta}_t$) must capture both the short-term effect of the news and persistent change in exposure. Importantly, it also must accommodate potential autocorrelation in exposure. The following model satisfies those objectives:

$$\bar{\delta}_t = c + c_t + \rho\left(\bar{\delta}_{t-1} - c - c_{t-1}\right) + \varphi\prime X_t + \sum_{j=1}^{J}\theta_j Surp_{j,t} + \epsilon_t, \tag{7}$$

$$\text{with } c_t = c_{t-1} + \sum_{j=1}^{J}\lambda_j Surp_{j,t} \text{ and } c_0 = 0.$$

The error term is assumed to be stationary with zero mean. The λ (θ) coefficients on the surprises capture the persistent (transitory) effect of the surprises on the average foreign exchange exposure. Except for the auxiliary equation expressing the persistent effects of macroeconomic news on the exposure coefficient, this is a standard regression, where X_t denotes a set of control variables.[6] We employ two types of control variables. The first group of controls is related to the foreign exchange rate: (i) the sign of the change in the foreign exchange rate (see, e.g., Bartram, 2004; Bartram and Bodnar, 2012; Chaieb and Mazzotta, 2013; Koutmos and Martin, 2007), (ii) the squared change in the foreign exchange rate (see, e.g., Muller and Verschoor, 2006) and (iii) the 'moneyness' of the option to export, that is, the accumulated recent exchange rate changes as in Boudt et al. (2015). The second group of controls consists of dummies for one-off events. Table 3 details the controls.

We estimate the model by non-linear least squares and account for the heteroscedasticity and autocorrelation in the residuals with HAC standard errors. Our sample contains 1672 daily observations, four indicators, and 486 announcements on 393 announcement days.

4. Estimated foreign exchange rate exposures

This section presents the results on the estimated foreign exchange rate exposures. Panel A of Table 4 shows that the cross-sectional average exposure has a positive mean over time. On average, if the foreign currency index appreciates by 1%, a firm's stock price increases by 1.09%. This means that the average firm typically benefits from a strengthening foreign currency. Most of the significant exposures are positive: at the 10% (5%) level, for instance, 38% (32%) of the (182 * 1,672 =) 304,304 delta coefficients are significantly positive, against just 6% (4%) significantly negative deltas.

There is substantial commonality between the firms' foreign exchange rate exposures. The average correlation between the firms' exposures is 0.52, and the first principal component of the matrix of foreign exchange exposures explains 54% of the variation in the foreign exchange rate exposure while the second component explains less than 4%. Additionally, the first principal component has a correlation of over 99% with the cross-sectional average of the estimated foreign exchange exposures. Given the high commonality, we focus the empirical analysis on the cross-sectional average exposure. The robustness analysis shows that the unconditional results are largely consistent with those conditional on firms categorized by sector and/or foreign sales.

Fig. 2 shows that the cross-sectional average exposure varies substantially over time and is actually negative at the beginning of the sample, during the financial crisis of 2008. It increases from 2009 onwards up to 2011 to levels of two or more, after which it returns to about zero. Mid-2011 the exposure starts to decrease again and is slightly negative at the end of the sample period. This appears to be related to the pattern of dollar depreciation and appreciation shown in Fig. 1.[7] That is, exposure falls, and turns negative when the USD is strong, consistent with a decline in the relative attractiveness of exports, as we discuss in SubSection 2.1.

[6] Note that by using the first order autoregressive model specification for $\bar{\delta}_t$ centered around $c + c_t$, the long run expectation of $\bar{\delta}_t$ is $c + c_t + \varphi' E[X_t]/(1-\rho)$. Since the controls have little explanatory power for $\bar{\delta}_t$, $c + c_t$ can thus be interpreted as a proxy for the local level of $\bar{\delta}_t$.

[7] The correlation between the 252-day moving averages of $\bar{\delta}$ and the exchange rate equals 0.55.

Table 3
Control variables. This table provides details on the control variables included in the analysis. Panel A shows the controls related to the foreign exchange rate. Panel B reports the one-off events included in the analysis. The one-off dummy $D_{q,t}$ $(q = 1, \ldots, Q)$ equals unity on days where potentially relevant news is released. Details on the Fed LSAP program can be found in Bauer and Neely (2014).

Variable	Description	
	Panel A: Controls based on the foreign exchange rate	
M_t	Moneyness, *i.e.* the distance between the exchange rate level at time t, S_t, and a recent reference level, $\bar{S}_t$, implemented as the 100-day look-back average of S (Boudt et al., 2015)	
$I(\Delta S_t > 0)$ and $I(\Delta S_t < 0)$	Two indicators for the sign of ΔS, (see, e.g, Chaieb and Mazzotta, 2013)	
ΔS_t^2	The squared change in the foreign exchange rate (see, e.g., Muller and Verschoor, 2006)	
	Panel B: One-off events	
Event	Date	Description
Coordinated interest rate cut	10-08-2008	Coordinated interest rate cut between the European Central Bank, Bank of England, Federal Reserve Bank, Bank of Canada, Swedish Riksbank and Swiss National Bank.
Joint currency intervention	03-17-2011	G-7 joint currency intervention to weaken the yen in the wake of the Thoku earthquake in Japan
OMT announcement	07-26-2012	ECB announcement of the Outright Monetary Transactions program by Mario Draghi: "Within our mandate the ECB is ready to do whatever it takes to preserve the euro. And believe me, it will be enough"
Fed LSAP program	11-25-2008	The initial "large-scale asset purchases" (LSAP) announcement
	12-01-2008	The Chairman's speech on LSAP
	12-16-2008	The FOMC states that it is considering expanding purchases of agency securities and initiating purchases of Treasury securities
	03-18-2009	The FOMC announces purchases up to an additional $750 billion of agency mortgage backed securities, $100 billion of agency debt and $300 billion of longer-term Treasury debt.
	08-10-2010	The Balance Sheet Maintained: Fed will reinvest principal payments from LSAP purchases in Treasuries
	09-21-2010	Statement projects that inflation "is likely to remain subdued for some time before rising to levels the Committee considers consistent with its mandate."
	11-03-2010	Statement announces purchases of $600 billion in Treasury securities
	08-22-2012	FOMC members "judged that additional monetary accommodation would likely be warranted fairly soon."
	09-13-2012	The Fed will purchase $40 billion of MBS per month as long as "the outlook for the labor market does not improve substantially . . .in the context of price stability" (https://www.federalreserve.gov/newsevents/pressreleases/monetary20120913a.htm)

Table 4
Summary of the estimated foreign exchange rate exposures of 182 U.S. multinational firms. The table reports average foreign sales ratio and the total (panel A) and incremental (panel B) foreign exchange rate exposures for all firms (All) and for seven GICS sectors. The table shows the average exposure (over the firms and over time) and the % of significantly positive and negative coefficients at the 5% and the 10% levels.

	All firms	Energy	Materials	Industrials	Cons. goods	Cons. staples	Health care	IT
% of sample	100.0	9.3	8.8	18.7	17.0	11.5	11.5	21.4
% of S&P 500	100.0	10.0	6.7	13.3	19.4	8.5	12.6	16.9
Foreign sales	48.8	48.0	52.0	42.3	41.7	49.9	48.1	58.6
Panel A: Total exposure								
Average	1.1	1.8	1.3	1.2	1.1	0.5	0.7	1.1
% + sign. at 5%	31.7	41.5	36.3	35.5	30.1	23.4	25.6	31.7
% + sign. at 10%	38.3	48.3	43.1	42.1	36.6	29.9	31.9	38.4
% − sign. at 5%	4.1	2.0	3.5	4.4	4.6	4.4	4.3	4.4
% − sign. at 10%	5.9	3.1	5.1	6.2	6.6	6.5	6.5	6.3
Panel B: Incremental exposure								
Average	0.1	0.5	0.2	0.1	0.1	−0.0	−0.0	0.1
% + sign. at 5%	7.5	11.7	8.8	7.9	6.4	6.2	6.3	7.2
% + sign. at 10%	11.4	17.3	13.5	11.8	10.0	9.8	9.8	10.7
% − sign. at 5%	5.8	3.4	4.6	5.4	6.0	6.7	6.8	6.3
% − sign. at 10%	9.0	5.4	7.2	8.5	9.3	10.2	10.6	9.8

5. Foreign exchange exposure dynamics

Fig. 2 shows that while the cross-sectional mean of foreign exchange exposure is positive on average, it substantially varies over time. This section investigates the macro determinants of exposure dynamics. We find that foreign exchange exposure is persistent and that NFP, price index and fed funds target announcements substantially affect average exchange rate exposure.

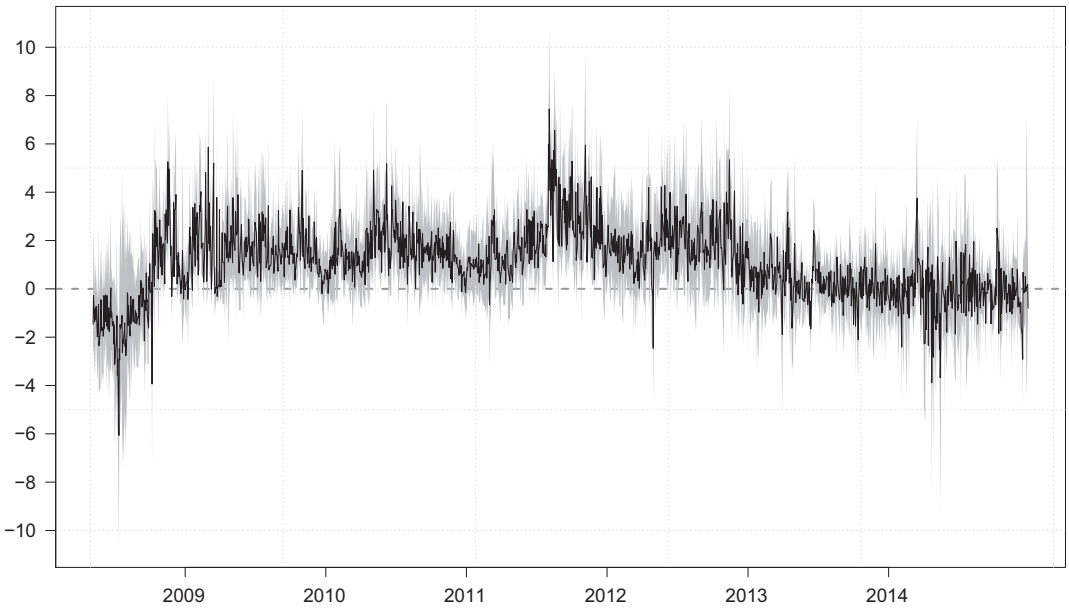

Fig. 2. Time variation in the average total foreign exchange rate exposure of 182 multinational U.S. firms. The plot shows the daily cross-sectional average of the estimated incremental foreign exchange rate exposure (in black) over the period May 2008–2014. The shaded region is the range between the 10% and 90% deciles of the daily cross-sectional foreign exchange rate exposures.

The second row of Table 5 reports that the average exposure's AR(1) coefficient — ρ in Eq. (1), — is positive, large, and significant, which is in line with the first hypothesis: the time-varying foreign exchange rate exposure of an internationally active firm exhibits positive serial correlation.

Eq. (7) distinguishes between short-lived and persistent effects from macroeconomic announcements. Columns 1 and 3 of Table 5 show the transitory effects of macroeconomic surprises. The inflation announcements– consumer price, producer price and export price index– have a significant transient impact on exposure. A one standard deviation positive shock to the export price index briefly reduces the exposure by 0.229, for instance. Consistent with Andersen et al. (2007), Mun (2012) argues that inflation surprises reduce subsequent stock prices because they reduce expected future economic growth, and imply more stringent monetary policy and an increase of interest rates. On the other hand, higher-than-expected inflation could depreciate the dollar through purchasing power parity (Neely and Dey, 2010).

Columns 2 and 3 of Table 5 display the persistent impact of the macroeconomic surprises on the average exchange rate exposure. NFP, consumer price index and FOMC target announcements have a significant persistent effect. Lahaye et al. (2011) identified NFP and FOMC announcements as the most important macroeconomic announcements across asset classes. NFP and fed funds target announcements provide information on expected growth and interest rates (Boyd et al., 2005). A positive NFP or fed funds target surprise persistently reduces foreign exchange exposure because it indicates that a stronger-than-expected U.S. economy will make domestic sales and imports of goods relatively more important in the medium-term.

One can calculate the dynamic response to macro news shocks in Eq. (7) in a manner similar to that used in vector autoregressions (VARs). The left-hand panel of Fig. 3 illustrates that a positive export price index announcement transitorily reduces foreign exchange rate exposure. Even a transitory effect lasts for several days because the average exposure is itself persistent through the ρ parameter in Eq. (7). On the other hand, the right-hand panel of Fig. 3 shows that a positive nonfarm payroll surprise persistently decreases average exposure.

Table 6 reports the dates of the ten macroeconomic announcements with the largest absolute impact on foreign exchange exposure. These announcements are concentrated in the first part of our sample (2008–2011), during the period of greatest financial market volatility and domestic economic weakness. The fourth column links the macroeconomic surprises to the currency exposure. The nonfarm payroll announcement of Dec. 5, 2008 is followed by a persistent raise in exposure by 1.04, for example. This is a substantial impact, comparable in size to the average exposure (1.09 over the entire sample).

6. Further analysis

Sections 6.1 and 6.2 characterize foreign exchange exposure, conditioned on sector and foreign sales ratio, respectively. Section 6.3 looks at the foreign exchange exposure of the market while Section 6.4 describes incremental exposure, over and above market exposure.

Table 5
Foreign exchange rate exposure dynamics. The dependent variable is the average daily exposure. The table shows the estimates and standard errors of the θs and λs, the coefficients that measure the persistent and transitory impacts, respectively, of the announcements (see Eq. (7)). The data set consist of 1672 daily observations and 486 announcements. Table 2 details the announcements while Table 3 details the controls. *, **, and *** denote significance at the 10%, 5%, and 1% levels with HAC standard errors (between parentheses).

	(1). Transitory		(2). Persistent		(3). Trans. + Pers.	
	Est.	SE	Est.	SE	Est.	SE
(Intercept)	0.333***	(0.054)	−0.599***	(0.233)	−0.618	(0.445)
AR(1)	0.686***	(0.021)	0.420***	(0.029)	0.417***	(0.036)
GDP Pers			−0.009	(0.043)	−0.008	(0.068)
GDP Trans	−0.052	(0.272)			0.125	(0.275)
NFP Pers			−0.297***	(0.032)	−0.297***	(0.062)
NFP Trans	−0.133	(0.151)			0.118	(0.127)
CPI Pers			0.067**	(0.027)	0.067***	(0.049)
CPI Trans	−0.075	(0.134)			−0.197*	(0.120)
PPI Pers			0.101**	(0.042)	0.112	(0.078)
PPI Trans	−0.192	(0.170)			−0.334*	(0.191)
EXPPI Pers			−0.009	(0.026)	−0.002	(0.049)
EXPPI Trans	−0.213*	(0.113)			−0.229**	(0.110)
TRADE Pers			0.022	(0.036)	0.038	(0.073)
TRADE Trans	−0.077	(0.101)			−0.142*	(0.084)
FOMC TARGET Pers			−0.221***	(0.022)	−0.227***	(0.041)
FOMC TARGET Trans	−0.082	(0.173)			0.113	(0.191)
FOMC 10Y Pers			−0.130**	(0.059)	−0.146	(0.095)
FOMC 10Y Trans	0.100	(0.172)			0.163	(0.186)
Controls	Yes		Yes		Yes	
Adj. R^2(%)	47.81		56.87		57.41	

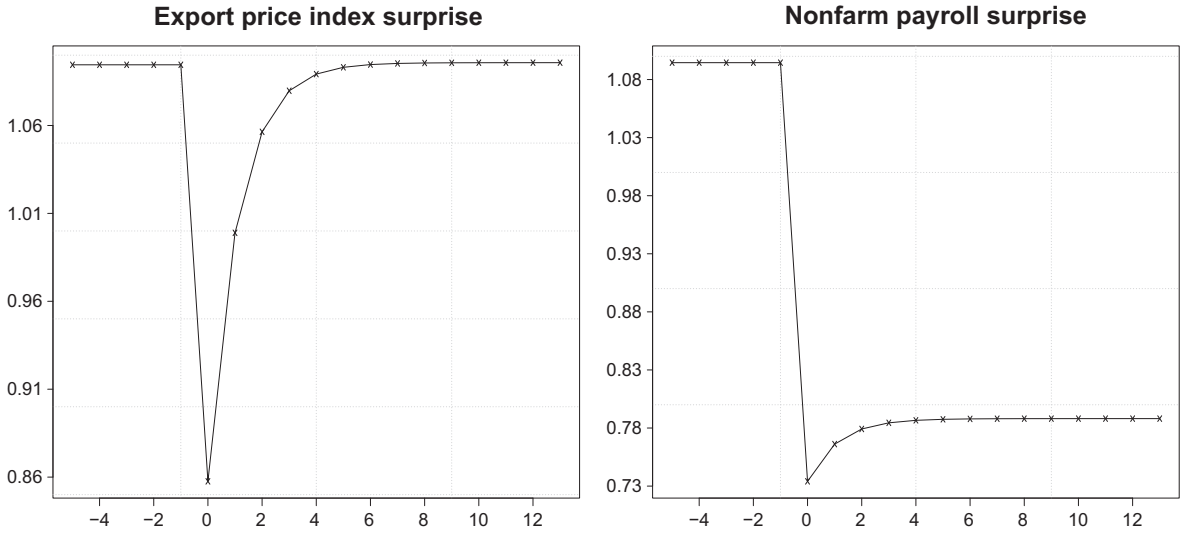

Fig. 3. The impact of a positive, one standard deviation surprise change in the export price index (left) and nonfarm payroll (right) on the average exchange exposure in an event window around the announcement. Day 0 is the day of the announcement.

6.1. Sector exposures

Although one might expect differing industry structures to produce differences in foreign exchange exposures (Marston, 2001), variation across sectors is ultimately an empirical issue. Table 4 reports substantial variation in the average estimated exposures for seven GICS sectors,[8] ranging from 0.7 (consumer staples and health care) to 1.8 (energy). Pharmaceutical imports could partly offset substantial medical equipment exports and reduce the health care sector's exposure (Chaieb and Mazzotta, 2013).

[8] The GICS sector classification consists of eleven sectors. We use seven of these sectors in our analysis. Sectors consisting of only a limited number of firms and the financial sectors are removed.

Table 6
The ten macroeconomic announcements with the largest absolute expected impact on the average foreign exchange rate exposure. P and T indicate whether the effect is persistent or transitory, respectively. Impact: the least squares estimate of the expected contemporaneous change in the average exchange rate exposure of the multinationals due to the surprise in the announcement, *ceteris paribus*. This equals $\hat{\lambda}_j \times Surp_j$ for a persistent effect and $\hat{\theta}_j \times Surp_j$ for a transitory effect (see Eq. (7)).

Announcement	Type	Date	Impact	Event
NFP	P	12-05-2008	1.15= −0.30 × −3.84	The economy shed 533,000 jobs in November, according to a government report Friday - bringing the year's total job losses to 1.9 million. November had the largest monthly job loss total since December 1974. (CNN, 12-05-2008)
	Intuition: Consistent with Hypothesis 2b, a weaker U.S. increases the relative importance of export-oriented activities.			
FOMC target	P	10-08-2008	1.03 = −0.23 × −4.48	The Bank of Canada, the Bank of England, the European Central Bank (ECB), the Federal Reserve, Sveriges Riksbank and the Swiss National Bank announce reductions in policy interest rates (Federal Reserve, 10-08-2008)
	Intuition: Consistent with Hypothesis 2b, a lower interest rates signals a weaker U.S. economy and thus increased relative importance of export-oriented activities.			
PPI	T	11-18-2008	0.91 = −0.33 × −2.77	U.S. producer prices declined by a record 2.8 per cent in October. The Labor Department said the producer price index recorded its third consecutive monthly reduction. (Reuters, 11-18-2008)
	Intuition: Consistent with Hypothesis 2a, an unexpected decline in producer price index leads to an immediate revaluation of stock prices and the foreign exchange rate. A lower-than-expected producer price index leads to an appreciation of USD and decrease in stock prices consistent with the law of one price, and therefore an immediate increase in the exposure.			
PPI	T	04-14-2009	0.91 = −0.33 × −2.77	Producer prices drop, biggest 12-month fall since 1950 (Reuters, 04-14-2009)
PPI	T	12-15-2009	−0.83 = −0.33 × 2.52	U.S. producer prices jumped a surprising 1.8 percent last month and industrial output rose firmly, sparking inflation jitters in financial markets. (Reuters, 12-15-2009)
FOMC target	P	12-16-2008	0.83 = −0.23 × −3.60	Federal Reserve cuts target interest rate below 1% for the first time. (Federal Reserve, 12-16-2008)
EXPPI	T	11-10-2011	0.81 = −0.23 × −3.54	The export price index declines by 2.1% (Bureau of Labor Statistics, 11-10-2011)
PPI	T	09-15-2009	−0.75 = −0.33 × 2.27	Producer prices jump 1.7% (Reuters, 09-15-2009)
PPI	T	03-16-2011	−0.75 = −0.33 × 2.27	The producer price index increased 1.6%. (Bureau of Labor Statistics, 03-16-2011)
EXPPI	T	09-11-2008	0.71 = −0.23 × −3.10	Prices for U.S. exports unexpectedly declined, down 1.7% for their first drop since October 2006. (Reuters, 09-11-2008)

Table 7 reports the dynamic impact of announcements on exposure by sector. The main results for the average cross-sectional exposure also hold for the sector exposures. NFP and FOMC target announcements persistently affect foreign exchange exposure. A higher-than-expected export price index temporarily decreases the exposure of all sectors, except for the energy sector. The impact of other announcements differs by sector.

6.2. Exposures conditional on the level of foreign sales

Prior research shows that a firm's foreign exchange rate exposure is positively related to its foreign sales (see, e.g., Dominguez and Tesar, 2006; He and Ng, 1998; Jorion, 1990; Williamson, 2001). In Table 8, we analyze whether the foreign sales ratio of a firm explains the dynamics of its foreign exchange exposure. Therefore, we categorize multinational firms into two groups for each year: those reporting the 25% lowest and 25% highest foreign sales ratios.

The average exposure of a high-foreign-sales firm is 1.14, while the average exposure of a low-foreign-sales firms is 0.91. This difference is statistically significant at 1% level. Otherwise, macro surprises affect the exposure of the two groups in very similar ways.

6.3. Market foreign exchange exposure

We proxy stock market returns with 10-min returns for the SPY exchange-traded fund, which tracks the S&P 500 index. Because multinationals make up between 52 and 62% of the market portfolio, the dynamic pattern of market exposure is very similar to that of average exposure, seen in Fig. 2, so we omit the market-exposure figure.

The joint analysis of the exposure coefficients for the market and the individual multinational is important for both *ex post* evaluation of the sources of portfolio risk, and the *ex ante* allocation decisions to reduce the exchange rate exposure of a portfolio.

To illustrate the *ex post* risk evaluation, we first note that market exposure depends linearly on individual exposures because the market return is a linear combination of individual stock returns:

$$\delta_{m,t} := \frac{\mathrm{cov}(r_{m,t}, s_t)}{\mathrm{var}(s_t)} = \frac{\mathrm{cov}\left(\sum_{i=1}^{n} w_{i,t} r_{i,t}, s_t\right)}{\mathrm{var}(s_t)} = \sum_{i=1}^{n} w_{i,t}\delta_{i,t}\iota_{i,t} + \sum_{i=1}^{n} w_{i,t}\delta_{i,t}(1-\iota_{i,t}), \tag{8}$$

Table 7
The foreign exchange exposure dynamics by GICS sector. The dependent variable is the average daily exposure of the firms in the sector. The data set consists of 1672 daily observations and 486 announcements. Table 2 details the announcements while Table 3 details the controls. *, **, and *** denote significance at the 10%, 5%, and 1% levels with HAC standard errors (between parentheses).

	Energy		Materials		Industrials		Cons. goods		Cons. staples		Health care		IT	
	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE
(Intercept)	1.42**	(0.51)	−0.41	(0.47)	−0.82	(0.57)	-1.31	(0.69)	−0.48	(0.32)	−0.46	(0.31)	−1.10**	(0.52)
AR(1)	0.28***	(0.03)	0.33***	(0.03)	0.43***	(0.05)	0.40***	(0.04)	0.37***	(0.04)	0.32***	(0.05)	0.35***	(0.04)
GDP Pers	−0.02	(0.09)	0.02	(0.07)	0.01	(0.08)	0.02	(0.09)	−0.02	(0.05)	−0.06	(0.06)	−0.01	(0.08)
GDP Trans	0.19	(0.34)	0.14	(0.28)	0.14	(0.32)	0.04	(0.34)	0.09	(0.19)	0.09	(0.20)	0.18	(0.30)
NFP Pers	−0.20***	(0.06)	−0.30***	(0.06)	−0.35***	(0.08)	−0.38***	(0.09)	−0.19***	(0.04)	−0.20***	(0.05)	−0.33***	(0.07)
NFP Trans	−0.04	(0.16)	0.11	(0.12)	0.14	(0.14)	0.15	(0.15)	0.07	(0.10)	0.04	(0.12)	0.16	(0.13)
CPI Pers	0.15**	(0.06)	0.11**	(0.05)	0.08	(0.06)	0.06	(0.07)	0.01	(0.03)	0.01	(0.04)	0.07	(0.05)
CPI Trans	−0.07	(0.20)	−0.33**	(0.12)	−0.22	(0.16)	−0.27	(0.18)	−0.18*	(0.09)	−0.21*	(0.11)	−0.18	(0.19)
PPI Pers	0.08	(0.08)	0.08	(0.07)	0.11	(0.09)	0.12	(0.10)	0.05	(0.05)	0.11*	(0.06)	0.17*	(0.09)
PPI Trans	−0.40	(0.26)	−0.36*	(0.20)	−0.32	(0.20)	−0.36*	(0.20)	−0.17	(0.14)	−0.32*	(0.17)	−0.41**	(0.20)
EXPPI Pers	0.08	(0.05)	0.03	(0.05)	−0.01	(0.06)	−0.04	(0.06)	0.00	(0.03)	0.01	(0.04)	−0.02	(0.05)
EXPPI Trans	−0.22	(0.17)	−0.22*	(0.12)	−0.24**	(0.11)	−0.25*	(0.13)	−0.13*	(0.07)	−0.26*	(0.10)	−0.24*	(0.13)
TRADE Pers	−0.04	(0.07)	0.08	(0.07)	0.04	(0.09)	0.06	(0.09)	0.03	(0.05)	−0.01	(0.05)	0.06	(0.08)
TRADE Trans	−0.13	(0.15)	−0.20*	(0.11)	−0.15	(0.09)	−0.14	(0.09)	−0.14***	(0.06)	−0.09	(0.07)	−0.17*	(0.09)
FOMC TARGET Pers	−0.16***	(0.05)	−0.21***	(0.04)	−0.26***	(0.05)	−0.28***	(0.06)	−0.14***	(0.03)	−0.18***	(0.03)	−0.26***	(0.05)
FOMC TARGET Trans	−0.10	(0.28)	0.02	(0.23)	0.09	(0.20)	0.03	(0.20)	0.25	(0.19)	0.15	(0.20)	0.16	(0.22)
FOMC 10Y Pers	−0.12	(0.08)	−0.14	(0.10)	−0.15	(0.11)	−0.17	(0.12)	−0.15***	(0.07)	−0.10	(0.08)	−0.13	(0.11)
FOCM 10Y Trans	0.26	(0.24)	0.19	(0.18)	0.20	(0.21)	0.23	(0.23)	0.19	(0.16)	0.19	(0.19)	−0.06	(0.20)
Controls	Yes		Yes		Yes		Yes		Yes		Yes		Yes	
Adj. R^2(%)	38.22		50.60		55.16		56.46		44.70		44.19		53.85	

Table 8
The foreign exchange exposure dynamics for firms conditional on the ratio of foreign sales to total sales. The low-(high-) foreign-sales category consists of the 25% firms systematically reporting the lowest (largest) percentage of foreign sales over 2008–2014. The dependent variable is the average daily exposure. The data set consist of 1,672 daily observations and 486 announcements. Table 2 details the announcements while Table 3 details the controls. *, **, and *** denote significance at the 10%, 5%, and 1% levels with HAC standard errors (between parentheses).

	(1). Low Foreign Sales		(2). High Foreign Sales	
	Est.	SE	Est.	SE
(Intercept)	−0.822	(0.500)	−0.775*	(0.456)
AR(1)	0.426***	(0.039)	0.372***	(0.037)
GDP Pers	−0.011	(0.068)	0.002	(0.070)
GDP Tran	0.093	(0.264)	0.142	(0.266)
NFP Pers	−0.290***	0.067	−0.300***	(0.062)
NFP Trans	0.124	(0.128)	0.134	(0.127)
CPI Pers	0.540	(0.052)	0.061	(0.051)
CPI Trans	−0.290**	(0.133)	−0.168	(0.137)
PPI Pers	0.094	(0.080)	0.131	(0.080)
PPI Trans	−0.313**	(0.175)	−0.372*	(0.210)
EXPPI Pers	−0.020	(0.049)	−0.000	(0.050)
EXPPI Trans	−0.196**	(0.103)	−0.247**	(0.120)
TRADE Pers	0.040	(0.073)	0.051	(0.077)
TRADE Trans	−0.149**	(0.067)	−0.079	(0.088)
FOMC TARGET Pers	−0.223***	(0.045)	−0.238***	(0.042)
FOMC TARGET Trans	0.113	(0.180)	0.176	(0.200)
FOMC 10Y Pers	−0.133	(0.098)	−0.125	(0.097)
FOMC 10Y Trans	0.180	(0.187)	0.104	(0.176)
Controls	Yes		Yes	
Adj. R^2(%)	56.38		54.47	
# of firms	31		31	
Average foreign sales ratio	22.13		77.29	

where $w_{i,t}$ denotes the weight (i.e., market capitalization) of firm i in the S&P 500 portfolio on day t, and $\imath_{i,t}$ is a dummy variable to indicate that firm i is included in our sample on day t. The contribution of the firms in our sample to the market exposure $\delta_{m,t}$ is $\sum_{i=1}^{n} w_{i,t}\delta_{i,t}\imath_{i,t}$. Table 9 shows the total exposure coefficients, weights, betas, incremental exposure coefficients, average foreign sales ratios and sectors of the ten most heavily weighted contributors over the sample.

The joint analysis of $\delta_{m,t}$ and the individual exposure coefficients is also useful in *ex ante* portfolio allocation. When a portfolio of stocks is hedged with the help of currency and stock-index futures, exposures should be estimated properly for both the individual shares and the market. To test the quality of our exposure estimates we set up a stocks-and-futures portfolio whose currency exposure should be zero. We then verify how well this works out in practice if one uses estimated exposures out of sample. In terms of the true conditional deltas, currency exposure should be entirely eliminated if a given portfolio of stocks is combined with an index-futures position of

$$b_t = -\frac{1}{\delta_{m,t}} \frac{\sum_{i=1}^{n} w_{i,t}\delta_{i,t}\imath_{i,t}}{\sum_{i=1}^{n} w_{i,t}\imath_{i,t}}. \tag{9}$$

In practice, the exposure coefficients in the hedge ratio b_t must be estimated on day $t-1$ and applied out of sample. The typical approach is to estimate b_t using the $\delta_{i,t}$ coefficients from a regression using daily returns with a 252-day rolling window.[9] Our alternative is to replace $\delta_{i,t}$ in Eq. (9) with the average of the past 252 values of $\delta_{i,t}$ estimated using intraday returns. We evaluate the precision of the estimation using the ex post realized exposure of the delta-neutral portfolio:

$$\delta_t^n = \hat{b}_{t|t-1}\delta_{m,t} + \frac{\sum_{i=1}^{n} w_{i,t}\delta_{i,t}\imath_{i,t}}{\sum_{i=1}^{n} w_{i,t}\imath_{i,t}}.$$

Hedging with an exposure based on 252 intraday samples instead of one sample with 252 daily returns reduces the average absolute value of δ^n from 0.19 to 0.13, a significant improvement at the 5% level, according to the Diebold and Mariano (1995) test.

6.4. Incremental foreign exchange exposure

In the above we studied the Adler and Dumas (1984) *total* foreign exchange exposure, which is estimated by regressing intraday stock returns on intraday foreign exchange returns. Prior work often adds a market return to this regression to estimate the incremental exposure of a firm's value to changes in foreign exchange rates. The latter regression interests a hedger who wants to use both currency and market-index futures to hedge a stock position. We therefore now study how including

[9] We use the open-to-close returns, *i.e.* we omit overnight returns, for the sake of comparability with the intraday sample.

Table 9
The top ten contributors to the market exposure. The table shows the top ten contributors' average total exposure ($\bar{\delta}_i$), average weight in the market portfolio ($\bar{w}_i$), average market beta ($\bar{\beta}_i$), average incremental exposure ($\bar{\gamma}_i$) as defined in Eq. (10), average foreign sales ratio (FS) and the GICS sector.

Firm	$\bar{\delta}_i$	$\bar{w}_i$ (%)	$\bar{\beta}_i$	$\bar{\gamma}_i$	FS (%)	Sector
Exxon Mobil Corp	1.10	3.27	0.87	0.24	71.72	Energy
Apple Inc	0.79	2.70	1.08	−0.15	56.17	IT
Chevron Corp	1.32	1.61	0.92	0.36	72.08	Energy
General Electric Co	1.27	1.72	1.12	0.12	52.92	Industrials
Microsoft Corp	0.86	2.10	0.96	−0.05	45.13	IT
Schlumberger Ltd	1.79	0.80	1.28	0.42	65.67	Energy
Intl Business Machines Corp	0.76	1.57	0.77	0.02	64.94	IT
Oracle Corp	0.95	1.16	0.84	0.07	56.87	IT
Conocophillips	1.40	0.73	0.98	0.39	40.67	Energy
Intel Corp	0.99	0.99	1.08	−0.06	84.19	IT

the market return affects the interpretation of the exposure coefficient and analyze how news impacts this incremental exposure.

To do so, we jointly estimate the firm's market beta $\beta_{i,t}$ and incremental exposure coefficient $\gamma_{i,t}$ for a given day t by regressing intraday company returns on intraday foreign exchange returns and the intraday stock-market returns:

$$r_{i,t,k} = \alpha_{i,t} + \beta_{i,t} r^m_{t,k} + \gamma_{i,t} s_{t,k} + \epsilon_{i,t,k}, \tag{10}$$

where $r_{i,t,k}$ is the log return of stock i during the k^{th} intraday period of day t, $r^m_{t,k}$ is the corresponding market return, $s_{t,k}$ is the trade-weighted exchange rate return and $\epsilon_{i,t,k}$ denotes the error term. We use the SPY exchange-traded fund, tracking the S&P 500 index, for the market return (e.g., Patton and Verardo, 2012).

Consider the time series plot of average γs across the 182 firms in Fig. 4. By construction, the market-value-weighted average of $r_{i,t,k}$ equals $r^m_{t,k}$. It follows that the market-value-weighted average γ across *all* S&P 500 firms is zero every day. In light of that, a positive average for our 182-firm subsample must mean this subsample has an above-average incremental exposure on that day. From the figure, the average incremental exposure in our sample is slightly negative in 2008, but edges upward afterwards. For instance, $\overline{\gamma}$'s time series average is 0.11 (panel B of Table 4), and significant positives are somewhat less rare than significant negatives. But this variation is modest, as is the variation over time compared to the average total exposure. The average incremental exposure occasionally spikes however, reaching 3.54 on the day of the Flash Crash in May 2010.

Unsurprisingly, the γs are small compared to the total exposures; compare Figs. 2 and 4, for instance, or panels A and B of Table 4. To understand why the incremental exposure of an internationally active firm is much smaller than its total exposure, it is useful to consider the following identity between total and the incremental exposure in the multivariate regression:

$$\gamma_{i,t} = \delta_{i,t} - \beta_{i,t}\delta_{m,t}, \tag{11}$$

where $\delta_{m,t}$ and $\delta_{i,t}$ are the total foreign exchange exposures of the market and firm i, respectively, $\beta_{i,t}$ is the market sensitivity[10] of firm i and $\gamma_{i,t}$ is the incremental foreign exchange exposure of firm i. Eq. (11) shows that the incremental exposure $\gamma_{i,t}$ captures only the extra exposure of company i over and above the market's.

Some studies have treated incremental exposure as the quantity of more interest, implicitly arguing that the $\beta_{i,t}\delta_{m,t}$ part is not "real" exposure, as it reflects the firm's sensitivity to the market movements rather than to the exchange rate. This view would be fine if the market return were an exogenous variable that affects both exchange rates and stock returns. The market return is not at all like that, though: it is the weighted average of the return on all firms i, and its own delta is the weighted average of all firms' deltas. That affects the interpretation. For instance, if all firms had similar total exposures and unit betas, each firm's incremental delta would be identically zero. Obviously, the correct conclusion would *not* be that firms are not exposed. Rather, it would mean that the firm has no extra exposure over and above the average firm, which is a rather different conclusion.

Table 10 breaks regression results down into the average incremental exposure of our internationally exposed subset of firms and market exposure. The market's exposure is autocorrelated and unsurprisingly responds to surprises in a manner similar to that of average total exposure. NFP and FOMC announcements have a persistent impact on market exposure while consumer and export price index announcements have a transitory impact on it.

The incremental exposure, in contrast, exhibits no significant autocorrelation, indicating that almost all persistence is common to the market. The average firm's exposure, $\delta_{m,t}$, picks up most of the dynamics in individual total exposure, leaving

[10] This is not the standard CAPM beta; it is the international-CAPM beta in either a two-country world or in a multiple-country world where all firms' exposures to bilateral exchange rates are proportional to those currencies' trade shares.

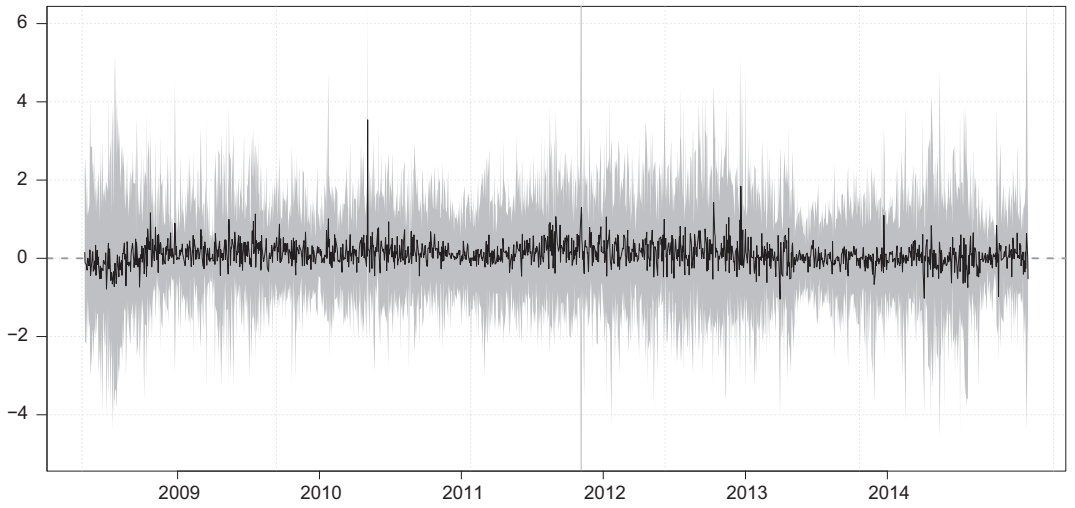

Fig. 4. Time variation in the incremental foreign exchange rate exposure. The time series plot shows the daily cross-sectional average of the estimated incremental foreign exchange rate exposure $\gamma_{i,t}$ (in black) over the period May 2008–2014. The shaded region is the range between the 10% and 90% quantiles of the daily cross-sectional incremental foreign exchange rate exposures.

Table 10
The incremental and market foreign exchange exposure dynamics. The dependent variable is the cross-sectional average daily incremental exposure (panel A) and market exposure (panel B). The data set consists of 1672 daily observations and 486 announcements. Table 2 details the announcements while Table 3 provides information on the controls. *, **, and *** denote significance at the 10%, 5%, and 1% levels with HAC standard errors (between parentheses).

	Incremental exposure		Market exposure	
	Est.	SE	Est.	SE
(Intercept)	−0.134***	(0.033)	−0.606	(0.437)
AR(1)	−0.009	(0.024)	0.417***	(0.037)
GDP Pers	0.010	(0.008)	−0.013	(0.061)
GDP Trans	0.022	(0.037)	0.113	(0.253)
NFP Pers	−0.027***	(0.004)	−0.268***	(0.056)
NFP Trans	−0.016	(0.028)	0.104	(0.120)
CPI Pers	0.008*	(0.004)	0.050	(0.044)
CPI Trans	−0.003	(0.033)	−0.201*	(0.104)
PPI Pers	0.024***	(0.008)	0.106	(0.070)
PPI Trans	−0.036	(0.033)	−0.312	(0.194)
EXPPI Pers	−0.009**	(0.004)	−0.002	(0.044)
EXPPI Trans	−0.008	(0.028)	−0.212**	(0.098)
TRADE Pers	0.008	(0.005)	0.049	(0.067)
TRADE Trans	−0.017	(0.024)	−0.172**	(0.085)
FOMC TARGET Pers	−0.018***	(0.004)	−0.213***	(0.036)
FOMC TARGET Trans	0.009	(0.059)	0.085	(0.197)
FOMC 10Y Pers	−0.008	(0.008)	−0.156*	(0.088)
FOMC 10Y Trans	−0.091*	(0.045)	0.224	(0.174)
Controls	Yes		Yes	
Adj. R^2(%)	10.37		56.16	

only a small, low-persistence extra component. Note that we would have missed this common autocorrelation totally if we had only worked with incremental exposures.

Table 10 shows that four macroeconomic announcements persistently affect the average incremental foreign exchange exposure at the 5% level. A higher-than-expected NFP or FOMC target announcement persistently decreases the incremental exposure, while a positive PPI shock persistently increases it. Only one type of surprise announcements has a significant transitory effect, namely the FOMC ten-year yield surprise. All announcements together explain only 10% of the incremental exposures, compared to 56% for the market's total exposure.

7. Conclusion

This paper uses intraday data to estimate daily foreign exchange exposure coefficients that covary with the value of the dollar at low frequencies and with news at high frequencies. Macroeconomic announcements affect foreign exchange exposure of U.S. multinational firms in a statistically and economically significant way.

We distinguish between short-lived and persistent effects of macroeconomic announcements. Transitory effects occur when news prompts a short-lived revaluation of stock prices and exchange rates. Persistent effects result from changes in the perceived relative future importance of import and export-oriented activities and therefore the foreign exchange rate exposure of the firm. Price index surprises have transitory impacts; NFP and FOMC target announcements carry information about future cash flows and discount rates and therefore persistently influence foreign exchange exposure. A lower-than-expected value for the federal funds target or NFP raises exposure because it signals a weaker U.S. economy and increased relative importance of export-oriented activities.

The impact of news on foreign exchange exposure is relevant for corporate (risk) managers, who must estimate the sensitivity of the firm's cash flows and value to changes in the foreign exchange rate. Also, investors or portfolio managers could incorporate these insights into their portfolio allocation and hedging decisions.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.jimonfin.2019.01.009.

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